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Interaction With Universities And Firm's Innovative Performance: Evidence From The Spanish Innovation Survey

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Abstract

This paper analyses the effect of interaction with universities on firms' innovation output, measured as the degree of novelty of product innovation. The analysis is based on a sample of 3,257 manufacturing firms, active in innovation, and located in Spain. We distinguish between two types of interaction mechanisms: cooperation in innovation activities and outsourcing of research and development (R&D) services. Using data from two waves of the Spanish innovation survey (2004 and 2007), we examine the effect of interaction in 2004 on subsequent product innovation in 2005-2007. The results show that neither cooperation with universities nor outsourcing of R&D services to these agents has a significant effect on product innovation. In other words, for Spanish manufacturing firms the acquisition of knowledge from universities does not represent an important strategy to introduce new products into the market. In contrast, cooperation with customers and acquisition of external R&D from other firms seem to be important for innovation, especially for firms pursuing more radical innovation.

1 Introduction

Many current economic theories on and approaches to innovation, to a greater or lesser extent, hold that individual firms are seldom capable of innovating independently and that a firm's internal technical capabilities are insufficient to cope with the challenges of the global market. Likewise, studies in the field of business management indicate that the search for new product ideas, new forms of organization and/or solutions to existing problems goes beyond the firm's boundaries to explore the capacities in other firms or institutions. In theory, a wider and more diverse search strategy will provide access to new opportunities and enable the firm to build new organizational competences based on the integration of complementary knowledge sets from external agents **(Teece, 1986; March, 1991).**

These approaches emphasise relations with external agents as an important strategy, which allows the firm to learn from other organisations, thereby increasing its innovation capabilities. For instance, cooperation with universities has received special attention in the innovation policies of many OECD countries. This government interest in university-industry collaboration is supported by a large body of economic research that highlights the benefits of the so-called 'science-industry relationship', and describes university research as one of the engines of industrial innovation (**Henderson et al., 1998; Mansfield, 1998).** Along these lines, a large body of literature has emerged that discusses the factors and motivations that lead some firms to use universities in their innovation activities. The determinants of university-industry cooperation are explored in several empirical works using different measures and taking account of different groups of explanatory variables. The literature on industrial organization focuses on the effects of different types of spillovers on the propensity of firms to cooperate (Belderbos et al., 2004a), while the management literature takes a more resource based perspective and analyses the relationships between university-industry collaboration and a set of organizational capabilities (**Miotti and Schawald, 2003; Arranz and Fernandez., 2008).**

However, the question of whether interaction with universities has a positive impact on the innovative performance of firms has relatively received less empirical attention. Although a number of recent papers have explored this aspect, many of these studies are hindered by their focus on a limited number of technological environments and industry sectors (e.g. biotechnology in developed countries). In addition, most studies are concerned primarily with the effect of other innovation activities (e.g. in-house research and development -R&D) and rather overlook the broader matrix of university-industry relationships that can span a broad range of industry sectors through the use of several different channels (collaboration, R&D outsourcing, licensing, etc.).

This paper analyses the role of interaction with universities in industry innovation, using a large-scale cross-industry sample of innovative manufacturing firms located in Spain. Spain is a technology follower country, demonstrated by its science and technology indicator scores, which are among the lowest in the EU. Another feature of the Spanish innovation system that is distinctive is the major importance of the public sector, which constitutes the principal source of knowledge. In 2004, this sector, which is comprised of universities and public research organisations, accounted for 45% of total national expenditure on R&D and employed more than 76% of the researchers in Spain. This is atypical for Europe as a whole; in other European countries almost half of all researchers are employed by private firms. In addition, according to the 4th Community Innovation Survey (CIS-4), cooperation between firms and research centres in Spain is lower than the European average.

In order to investigate the role of the universities on industrial innovation, we build on previous studies that explore the effects of R&D cooperation on firm's innovative performance using data from national innovation surveys **(Aschoff and Schmidt 2008; Amara and Landry, 2005; Belderbos et al., 2004b**).We extend this work by considering two types of strategies thorough which firms draw on knowledge generated by universities: a) cooperation in innovation activities, and b) contracting out R&D to universities. In so doing, we attempt to integrate this investigation of the effectiveness of university–industry links into an analytical framework that considers two types of strategies for acquiring external knowledge: cooperation and outsourcing of R&D to universities. This represents an important contribution since there are several studies on the effect of industry cooperation with universities, but few investigations of the relation between outsourced research and innovation output.

Another contribution of this paper is that we use data on a large sample of innovating firms come from two waves of the Spanish Innovation Survey (2004 and 2007). These data allows us more accurately to analyse the effect of relations with scientific agents on innovation, by introducing time lagged variables. This is an important methodological novelty compared to the majority of the existing studies which use cross-sectional data (referred to only one wave of the innovation survey), which raises questions about causality relations.

The remainder of the paper is organised as follows: Section 2 provides a brief review of the literature; Section 3 describes the methodological aspects of the empirical study, the data, measurement of the variables, and the econometric specifications; Section 4 presents the results; and Section 5 offers some conclusions from the study.

2 Literature review

The role of universities in industrial innovation has become a favourite topic for analysis and there is a large body of theoretical and empirical literature on the determinants of university-industry collaboration. Work within the frame of the industrial organisation literature focuses mostly on the relationships between different types of spillovers and R&D cooperation while the management literature mainly examines the impact of different firm level characteristics (size, age of the firm, R&D intensity) as factors determining the propensity of firms to collaborate with universities. Studies in this latter field provide several insights into the motives and problems associated with this type of collaboration. In general, the results of these studies suggest that the main motivation to collaborate with universities is the possibility to access new knowledge and increase the internal capacity of firms **(Hagedoorn et al., 2000)**.Studies also indicate that the use of universities as knowledge sources is more widespread in science-based technology fields (**e.g. Klevorick et al., 1995**). Thus, it has been suggested that the technological capability of the firm (measured as investment in internal R&D) is directly related to the use of universities as a source of knowledge for innovation (Laursen and Salter, 2004; Mohnen and Hoareau, 2003). On the other hand, the evidence related to firm size is more contradictory, with some studies reporting a positive relationship **(Miotti and Sachwald, 2003; Bayona et al., 2002**) and some a non-significant one **(Abramovsky et al., 2009**). The influence of spillovers - especially those derived from scientific agents - is usually found to be positive **(Belderbos et al., 2004a)**

Overall, although a considerable amount of research has been devoted to analysing the determinants of university-industry collaboration, rather less attention has been paid to analysing the effects of these interactions on innovation performance. There are some studies that use data from CIS-type surveys; for instance, based on data for a large sample of Dutch innovating firms, **Belderbos et al. (2004b**) find that firms that cooperate with universities in their R&D activities show higher sales growth due to new products than firms that do not cooperate. This result is in line with those in **Lööf and Broström (2008**) and **Aschoff and Schmidt (2008**), based respectively on the Swedish and German CIS, which find that cooperation with scientific agents (universities or research institutions) has a positive effect on the share of sales of products new to the markets. **Amara and Landry (2005**), using the 1999 Statistics Canada Innovation Survey, regress the degree of novelty of product innovation on a variable indicating the use of scientific agents (universities included) as sources of information and find a significant and positive relationship. Specifically, they find that the use of universities as information sources increases the likelihood of radical innovations.

The above studies all reinforce the idea that universities are more likely than other external partners to stimulate radical innovation in firms. However, there are also studies that also use data from innovation surveys, and come up with different conclusions. **Miotti and Sachwald (2003**), for instance, find that cooperation with public institutions has no significant effect on the share of innovative products in turnover. **Laursen and Salter (2004**), using the UK innovation survey, conclude that only a limited number of firms draw directly on universities as their source of information or knowledge for innovative activities. These authors indicate also that, compared to clients or suppliers, universities are only moderately important, and suggest that the recent literature perhaps tends to overestimate the role of universities as direct sources of knowledge for innovation.

It can be seen, therefore, that the studies conducted so far on the effect of university-industry links on innovation, have produced contradictory results. In general, the results obtained are related to the definition of the variables, the estimation techniques used and even the countries involved. This points to the need for further research on the role of the university in the innovation process, and indicates that it might be a mistake to take for granted the effectiveness of university-industry links.

Bearing this in mind, we conduct an analysis of the effect of interaction with universities on industrial innovation in the context of Spanish manufacturing firms. This study advances the existing research by distinguish between two types of interaction mechanisms: cooperation in innovation activities and outsourcing of R&D services. The literature review reveals that the research in this field mostly concentrates on the relation between R&D collaboration and innovation output and is less concerned about the role of other strategies to acquire knowledge from universities. Thus, while there are several works investigating the effect of R&D cooperation or alliances and joint ventures, little is known on the relation between contract R&D (outsourcing of R&D) and innovation performance[1]. We are interested in the following questions: i) does the acquisition of knowledge from universities influence the level of innovativeness of the firm? ii) what strategy is more effective to improve the firm's innovative performance: R&D cooperation or R&D outsourcing? iii) are linkages to universities more favourable for innovation than links to other agents?

3 Methodology

3.1 Description of the database

The empirical analysis uses data from two waves of the Spanish Innovation Survey, which is based on the OECD's Oslo Manual. These data are collected by the Spanish National Statistics Institute (INE) and are available to researchers via the Spanish Technological Innovation Panel (PITEC). PITEC is organized as a set of panel data,

[1] An exception is the paper by Vega et al. (2009) who explore the effect of both cooperation and R&D outsourcing on innovative performance of Spanish manufacturing firms. However, in this study the authors do not distinguish between interaction with universities and interaction with other agents.

collected using a relatively consistent methodology over several time periods; it has wide sectoral coverage and includes both manufacturing and service sectors. The unit of analysis (i.e. each observation) is the single enterprise, regardless of whether it is part of a larger group or is an independent firm.

Data are available from five successive waves of the Spanish Innovation Survey (from 2003 to 2007); in this paper we use the data corresponding to the 2004 and 2007 surveys. This is appropriate since several of the questions in the survey refer to a three year period, and especially those related to the innovation outputs (product and process innovation) and to cooperation with external agents. This generates overlaps between variables from consecutive surveys or even two yearly surveys, which could result in overestimation of some innovation strategies (including cooperation) in the absence of appropriate correction. Thus, our decision to use data from the 2004 and 2007 surveys in order that we do not have overlaps between key variables analysed. For instance, we can relate cooperation during the period 2002-2004 (taken from the 2004 survey) to the introduction of new products onto the market during the period 2005-2007 (taken from the 2007 survey).[2] The use of lagged explanatory variables allows us to minimize the simultaneity problems that might arise between these variables[3].

The survey asks firms whether they have introduced a new product or process, or whether they had ongoing or abandoned innovation activities during the period covered by the survey. A positive answer to one of these questions classifies them as *innovators*.

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[2] We do not consider 2003 survey data because the sampling procedure for that year was different. For reasons related to opportunity and viability, in 2003 PITEC started with only two samples: the sample of firms with 200 or more employees and the sample of firms with intramural R&D expenditure. From 2004 it inlcuded, the sample of firms with fewer than 200 employees, external R&D expenditure and no intramural R&D expenditure; and a representative sample of firms with fewer than 200 employees and no innovation expenditure.

[3] Innovation strategies and innovation outputs may be determined simultaneously or may be dependent jointly on a third factor, which we do not observe(**Mairesse and Mohnen, 2010**). In this sense, when using cross-sectional data it is difficult to make statements about the directions of causality

We used this selection criterion to restrict our analysis to the subsample of *innovative firms*. This decision was drive mainly by the questionnaire design: only innovator firms answered the full questionnaire, including those questions related to cooperation with external agents. In addition, we include only those firms observed for the two waves of the survey mentioned above, and belonging to manufacturing sector; after deleting observations with missing values, we are left with a sample of 3,257 manufacturing firms.

3.2 Empirical strategy and definition of the variables

The aim of the empirical analysis is to identify whether the relations that firms establish with universities (via cooperation or outsourcing) affect their innovative performance. To this end we use the following econometric specification:

$$\begin{aligned} DEGINN_i &= \alpha_0 + \alpha_1 X_i + \alpha_2 Coop\_uni_i + \alpha_3 Coop\_group_i + \alpha_4 Coop\_\sup p_i \\ &+ \alpha_5 Coop\_client_i + \alpha_6 Coop\_comp_i + \alpha_7 Coop\_consul\tan ts_i + \alpha_8 Coop\_pro_i \\ &+ \alpha_9 Coop\_tc_i + \alpha_{10} R\&D\_uni_i + \alpha_{11} R\&D\_firms_i + \alpha_{12} R\&D\_other \\ &+ \alpha_{13} inhouse\_R\&D_i + \alpha_{14} Equipment + \alpha_{15} Tecno \end{aligned} \quad (1)$$

The explanatory variables used in the analysis are measured for the preceding period. That is, while the dependent variable is taken from the 2007 survey, the explanatory variables related to firms' cooperative behaviour and use of other innovation strategies, are based on 2004 survey. This procedure allows us to control for time lags in the determinants and outputs of the innovation process. Following the approach in **Belderbos et al. (2004b),** we can posit that innovation activity requires some time to translate into innovation output, therefore, the impact of R&D cooperative and R&D outsourcing on innovation should become more obvious in the subsequent three years.

The dependent variable used to measure the firm's innovation output is *degree of* *innovation (DEGINN).* This variables takes three values depending on the novelty of the product innovation developed: 0, if the firm did not introduce any new or improved products onto the market during the period 2005-2007; 1, if the product introduced in that period was new to the firm; and 2, if the product introduced was new to the market. This variable allows us to identify the factors relevant for the development of new products and to distinguish which has the greatest effect on the development of major innovations (products new to market). Along these lines, several studies emphasise the importance of knowledge sourcing from universities for firms pursuing more radical rather than incremental innovations (**Amara and Landry, 2005; Kaufmann and Tödtling, 2001; Tether, 2002).**

We use two types of explanatory variables: those related to the interactions between firms and external agents and those related to the use of other innovation strategies. All are taken from the 2004 survey. To analyse the effect of cooperation we draw specifically on the responses to questions about cooperation with external agents for R&D and innovation activities, during the period 2002–2004. Although the main objective is to analyse the effect of industry collaboration with universities, we control also for the effect of other types of cooperation. We define eight dummy variables (one for each type of collaborative partner included in the survey), which take the value 1 if the firm indicates engagement in active cooperation during 2002-2004 with the respective partner.

As well as analysing the relation between university-industry cooperation and innovation output, we examine the effect of another external knowledge sourcing strategy, namely R&D outsourcing. We draw on the responses to a question in the Spanish Innovation Survey that asks firms to estimate expenditure on externally provided R&D services for the last year covered by the survey. The questionnaire distinguishes between seven types of external suppliers of R&D services and two different locations (national and abroad): firms within the group; other firms; public bodies; research associations; universities; and private non-profit organisations. This information allowed the construction of a dummy variable for whether the firm outsourced R&D activities to universities (located in Spain or abroad) in the year 2004. We used this information to build two variables for whether the firm has sub-contracted R&D activities to other firms (within the same group, or not) or to other agents (public bodies, research associations, non-profit organisations).

In the analysis we control also for the effect of other innovation strategies. We include in the model three specific variables related to: a) the development of in-house R&D activities; b) the acquisition of machinery, equipment and software; and c) the acquisition of other external knowledge (purchase or licensing of patents and non-patented inventions, know-how, etc.). These strategies are measured using dummy variables that take the value 1 if the firm has used the strategy during the period 2002–2004, and 0 otherwise.

Finally, the X-vector in the model consists of other firm level control variables, such as size, dummy variables controlling for belonging to a group, employees' skills, firm age, market orientation, and three dummies controlling for the technological intensity of the sector in which the firm operates. Table 1 presents the definition of these variables.

As our analysis includes only *innovators,* there is a selection problem. To address this we employed a two-stage model (**Manning et al., 1987**). In the first stage of our analysis, we ran a general (selection) model using all available observations and considering the dependent variable INNOVATOR to indicate whether or not the firm is an innovator. This allowed us to calculate the probabilities of each firm becoming an innovator, (PINN). In the second stage, we ran the main model in which the dependent variable was the degree of novelty of product innovation. In this stage, non-innovator firms were dropped from the analysis, but the PINN variable was included as an additional independent variable. According to **Haas and Hansen (2005)**, this procedure is appropriate when the dependent variable in the selection model is observed rather than estimated, and is more appropriate than a Heckman selection model since the dependent variable in the main model is not continuous.[4]

[4] INNOVATOR, used as dependent variable in the selection model, is a dummy variable that takes the value of 1 if the firm is an innovator and 0 otherwise. Consistent with previous studies, we include as explanatory variables different measures related to: firm size, export orientation, belonging to a group, and industry dummies. We also include a number of variables measuring the obstacles to innovation (cost, lack of resources, lack of technological/market information, lack of technological opportunities, lack of demand for innovations).

Variable	Description	Scale of Measurement
DEGINN	Degree of novelty of product innovation introduced in 2005-2007	0: the firms introduced no new product into the market 1: products were introduced that were new to the firm 2: products were introduced that were new to the market e
SIZE	Firm size	Logarithm of Firm's number of employees
Equipment	Purchase of machinery and equipment	Dummy variable: 1 if the firm was engaged in acquisition of machinery and equipment during 2002-2004 period, and 0 otherwise
TECNO	Acquisition of intangible technology in the form of patents, trademarks, software	Dummy variable: 1 if the firm was engaged in acquisition of external knowledge in the form of patents, non-patented inventions, licences, disclosures of know-how during 2002-2004 period, and 0 otherwise
Inhouse_R&D	In-house R&D	Dummy variable: 1 if the firm was engaged in internal R&D activities during 2002-2004 period, and 0 otherwise
Coop_group	Cooperation with other firms in the same group in R&D and innovation activities, in 2002-2004	Dummy variable: 1 if the firm has cooperated with this agent, and 0 otherwise
Coop_Clients	Cooperation with clients in R&D and innovation activities in 2002-2004	Dummy variable: 1 if the firm has cooperated with this agent, and 0 otherwise
Coop_Supp	Cooperation with suppliers in R&D and innovation activities in 2002-2004	Dummy variable: 1 if the firm has cooperated with this agent, and 0 otherwise
Coop_Comp	Cooperation with competitors in R&D and innovation activities during the period 2002-2004	Dummy variable: 1 if the firm has cooperated with this agent, and 0 otherwise
Coop_consultants	Cooperation with consultants, laboratories and R&D firms in R&D activities and innovation in 2002-2004	Dummy variable: 1 if the firm has cooperated with this agent, and 0 otherwise
Coop_uni	Cooperation with universities in R&D activities and innovation in 2002-2004	Dummy variable: 1 if the firm has cooperated with this agent, and 0 otherwise
Coop_pro	Cooperation with public research bodies in R&D activities and innovation in 2002-2004	Dummy variable: 1 if the firm has cooperated with this agent, and 0 otherwise
Coop_tec	Cooperation with technology centres in R&D activities and innovation in 2002-2004	Dummy variable: 1 if the firm has cooperated with this agent, and 0 otherwise
R&D_uni	Outsourcing of R&D activities to universities	Dummy variable: 1 if the firm has outsourced R&D services to universities in 2004, and 0 otherwise
R&D_firm	Outsourcing of R&D activities to other firms	Dummy variable: 1 if the firm has outsourced R&D services to other firms in 2004, and 0 otherwise
R&D_other	Outsourcing of R&D activities to other agents	Dummy variable: 1 if the firm has outsourced R&D services to other agents (public bodies, non-profit organisations, research associations) in 2004, and 0 otherwise
High_skill	Firm’s human capital level	Percentage of employees with a higher education degree
Start-up	Firm age	Dummy variable: 1 if the firm was established after 1 January 2002
Market	Export orientation	Dummy variable: 1 if the firm sells its goods or services in other countries, and 0 otherwise
GROUP	Firm belongs to a group	Dummy variable: 1 if the firm belongs to a group, and 0 otherwise

Table 1. Description of variables

Bearing in mind that the dependent variable (DEGINN) in the main model can take three values, the estimation technique chosen was multinomial logistical regression. The reference category for the analysis is the one in which the firm did not introduce any new product into the market during the period 2005-2007. Consequently, the coefficients estimated by the regression model represent the marginal change in the logarithm of the odds of an assessment by the firm of the introduction into the market of products that are new to the firm (minor innovations) or new to the market (major innovations) over the category assessing the non-introduction of a new product, based on the marginal change in the explanatory variables.

3.3 Descriptive statistics

Table 2 reports the descriptive statistics and simple correlations of the variables used in the regression analysis.

Table 2 shows that 72% of the firms engaged in product innovation during the 2005-2007 period: 28.8% introduced products new to the firm; 43.2% introduced products new to the market. This high percentage of innovators is not surprising bearing in mind that the sample consists only of *innovator firms.*

We can see also that 14% of the firms engaged in active cooperation with universities: this type of collaboration is second in importance after cooperation with suppliers. These results coincide with the pattern in **Castro and Fernández (2006)**, and demonstrate that the levels of cooperation for Spanish firms are generally low and that those firms that do collaborate tend to partner with scientific institutions rather than clients, consultants or other enterprises. When we look at R&D outsourcing, however, universities are not the most popular partner: firms tend to outsource external R&D more to other firms (29%) than to universities (11%).

In the case of other innovation strategies, we see that in-house R&D is the most frequent strategy. Almost 90% of firms conducted some R&D during the period 2002-

2004. Also, 49% of firms acquired machinery and equipment for innovation, and 15% purchased other external knowledge (patents, licences, etc.).

Table 2 also shows the distribution of cases by sectoral classification. Fifty per cent of the sample or 1,634 firms are in low technology sectors, 1,231 (38%) firms in medium technology sectors and 392 firms (12%) are in high technology sectors. These figures indicate an over-representation of high technology sectors in the sample based on the distribution of the population of innovative firms in Spain (around 6%).

	Mean	SD	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
DEGINN (1)	1.09	0.84	1																					
Coop_group (2)	0.09	0.29	.077**	1																				
Coop_supp (3)	0.16	0.36	0.145**	0.299**	1																			
Coop_client (4)	0.10	0.30	0.142**	0.293**	0.427**	1																		
Coop_comp (5)	0.06	0.24	0.081**	0.136**	0.229**	0.246**	1																	
Coop_ consultants (6)	0.11	0.31	0.089**	0.205**	0.342**	0.296**	0.205**	1																
Coop_uni (7)	0.14	0.35	0.105**	0.256**	0.317**	0.307**	0.253**	0.377**	1															
Coop_pro (8)	0.07	0.25	0.103**	0.181**	0.226**	0.206**	0.219**	0.281**	0.406**	1														
Coop_tec (9)	0.14	0.35	0.129**	0.260**	0.357**	0.354**	0.244**	0.359**	0.353**	0.361**	1													
R&D_uni (10)	0.11	0.31	0.029	0.121**	0.070**	0.129**	0.113**	0.115**	0.400**	0.185**	0.098**	1												
R&D_firms (11)	0.29	0.45	0.057**	0.169**	0.154**	0.079**	0.094**	0.165**	0.083**	0.063**	0.067**	0.104**	1											
R&D_other (12)	0.14	0.35	0.075**	0.109**	0.079**	0.129**	0.118**	0.177**	0.166**	0.203**	0.313**	0.187**	.074**	1										
inhouse_ R&D(13)	0.89	0.32	0.167**	0.004	0.051**	0.081**	0.019	0.028	0.101**	0.067**	0.062**	0.051**	-0.166**	0.004	1									
Equipment (14)	0.49	0.50	0.119**	0.076**	0.127**	0.095**	0.065**	0.070**	0.059**	0.045*	0.063**	0.062**	0.098**	0.072**	-0.060**	1								
Tecno (15)	0.15	0.36	0.093**	0.068**	0.131**	0.064**	0.104**	0.085**	0.093**	0.075**	0.074**	0.092**	0.130**	0.074**	-0.025	0.219**	1							
High_tec (16)	0.12	0.33	0.042*	0.022	-0.021	0.039*	0.032	0.036*	0.101**	0.044*	-0.016	0.117**	0.055**	0.015	0.068**	-0.012	0.025	1						
Medium_tec (17)	0.38	0.48	0.093**	0.041*	-0.011	0.065**	0.013	-0.033	0.023	0.025	0.013	-0.003	-0.053**	-0.03	0.089**	-0.059**	-0.004	-0.288**	1					
Low_tec (18)	0.50	0.50	-0.117**	-0.054**	0.025	-0.088**	-0.033	0.009	-0.088**	-0.053**	-0.002	-0.073**	0.015	0.02	-0.130**	0.065**	-0.012	-0.371**	-0.782**	1				
Group (19)	0.40	0.49	.047**	0.362**	0.103**	0.084**	0.038*	0.075**	0.103**	0.074**	0.070**	0.081**	0.118**	0.047**	0	0.044*	0.073**	0.004	0.011	-0.013	1			
Size (20)	4.21	1.28	.040*	0.242**	0.151**	0.060**	0.058**	0.106**	0.109**	0.087**	0.093**	0.072**	0.117**	0.063**	-0.026	0.099**	0.118**	-0.083**	-0.061**	0.113**	0.504**	1		
high_skill (21)	18.32	17.76	.118**	0.017	0.007	0.080**	0.062**	0.038*	0.121**	0.088**	0.039*	0.133**	0.008	0.055**	0.124**	0.011	0.041*	0.294**	0.131**	-0.318**	0.008	-0.248**	1	
Start-up (22)	0.02	0.12	0.024	0.021	0.001	0.007	0.01	0.037*	0.034	0.025	0.007	0.013	0.014	0.013	-0.002	0.002	0.019	0.015	-0.015	0.005	-0.006	-0.120**	0.029	1
Market (23)	0.84	0.37	.056**	0.032	0.068**	0.049**	0.024	0.046**	0.067**	0.050**	0.063**	0.039*	0.018	0.055**	0.057**	0.050**	0.044*	-0.008	0.071**	-0.063**	0.123**	0.227**	0.075**	-0.055**
*** Significance at 1%.																								
** Significance at 5%.																								

Table 2. Descriptive statistics and correlations (n=3257)

The correlation matrix highlights some interesting aspects. Cooperation with universities in R&D and innovation activities is positively related to other types of cooperation. Actually, all types of cooperation considered in the survey show a positive correlation to each other. This result is in line with previous research showing that a firm that cooperates with an external agent is more likely to cooperate with other agents. Also, there is an important correlation between university collaboration and R&D outsourcing to universities. This fact might raise some concern about the possibility of multicollinearity considering that we use these variables simultaneously in the analysis. However, we ran some checks based on excluding these variables one at a time, and the results did not change in any important way.

Table 2 shows there are significant correlations between the different innovation strategies and the sectoral classifications. The variables representing association with a university (via cooperation or R&D outsourcing) are positively correlated with the variable indicating that the firm belongs to high-technology sectors, but negatively related to the variable representing low-technology sectors. Thus, the use of universities as a source of knowledge for innovation seems to be more widespread in higher technological intensity sectors, as suggested by previous studies (**Hagedoorn, 1993; Wang, 1994)**. In fact, 24% of firms in high-technology sectors have cooperated with universities in innovation activities and 21% outsourced R&D to a university; the respective proportions for low technological intensity firms are 11% and 9%.[5]

Internal R&D activity is also positively related to cooperation, and especially to

[5] *F-tests* show that these differences are significant. We also found significant differences between these two sectoral categories along other key parameters, such as in-house R&D, personnel with higher education degrees, firm size and acquisition of machinery and equipment. Thus our findings are consistent with the literature in showing that the more technology-intense the industry, the more frequent the development of internal R&D activities and the higher the level of education of the firm's personnel. Firms in low-technology sectors tend to draw more on the 'embodied' knowledge represented by the purchase of machinery and equipment. These results are available from the authors on request.

cooperation with universities. This latter result may be an indication of the twofold effect of internal R&D, that the greater the effort expended on this activity, the better the ability of the firm to identify and use sources of scientific knowledge. This is not to say that firms that do not cooperate with scientific agents do not perform in-house R&D, but rather that those that do cooperate are generally more active in this respect (Bayona et al., 2002). A similar relation exists between in-house R&D and R&D outsourcing from universities.

4 Results

The parameters estimated for the selection model (not reported here for reasons of space) indicate that the firm's export orientation and factors related to the obstacles to innovation, have a significant effect on the probability of being an innovator. On the basis of this first stage model, we calculated the PINN variable, which is exploited in the second-stage model.

Table 3 presents the results of the multinomial logistic estimation of equation (1). In general terms, the econometric specifications considered have acceptable predictive power, and the Chi-squared value for the degrees of freedom suggests rejection of the null hypothesis that all parameters except the intersection are equal to zero with a significance level of 1%.

The variables of interest are the two channels through which firms acquire knowledge generated in universities. The results show that neither cooperation with universities nor R&D outsourcing to a university has a significant effect on product innovation. In other words, for Spanish manufacturing firms, the acquisition of knowledge from a university is not an important strategy for the introduction of new products into the market. Similarly, cooperation with public research institutes does not a significant effect.

Although these results differ from much of the empirical literature related to the role of scientific agents in the industrial innovation (see section 2), it is in line with studies demonstrating the limited role of cooperation with universities and public research organisations on the competitiveness of Spanish manufacturing firms **(Alvarez et al., 2005; Vega-Jurado et al., 2008**). These results are also in line with Laursen and Salter's (2004) findings that only a limited number of firms draw on universities for their innovative activities; thus, its relevance as a direct knowledge source for innovation may have been overestimated.

The results also indicate that the determinants of innovation vary depending on the level of innovativeness. For incremental innovation (products new to the firm), in-house R&D is the only strategy that has a positive and significant effect. For radical innovations (products new to the market), in-house R&D, acquisition of machinery and equipment, cooperation with clients or customers, and outsourcing of R&D services to other firms all show positive and significant effects.

Independent variables	New to the firm/did not innovate		New to the market/did not innovate	
	Coefficient (β)	**Exp (β)**	**Coefficient (β)**	**Exp (β)**
intercept	-3.515		-5.294	
Coop_group	0.173	1.188	-0.113	0.893
Coop_supp	0.062	1.064	0.077	1.08
Coop_client	0.168	1.184	**0.423****	1.527
Coop_comp	0.079	1.082	0.156	1.169
Coop_consultants	-0.16	0.852	-0.259	0.772
Coop_uni	-0.114	0.892	-0.042	0.959
Coop_pro	0.326	1.386	0.271	1.311
Coop_tec	-0.103	0.902	0.062	1.064
R&D_uni	-0.039	0.962	0.143	1.154
R&D_firms	0.046	1.047	**0.226****	1.254
R&D_other	0.008	1.008	-0.031	0.969
inhouse_R&D	**0.674*****	1.962	**1.325*****	3.762
Equipment	0.129	1.137	**0.261****	1.298
Tecno	0.167	1.181	0.202	1.223
High_tech	**0.323***	1.381	**0.379****	1.461
Medium_tech	**0.375*****	1.455	**0.305****	1.356
Low_tech	0b	.	0b	.
Group	-0.026	0.974	0.04	1.04
Size	**0.229*****	1.257	**0.309*****	1.362
high_skill	**0.011*****	1.011	**0.018*****	1.019
Start-up	0.164	1.179	0.258	1.295
Market	**0.301****	1.351	**0.368****	1.445
PINN	Included		Included	
R^2: 0.14				
Chi square (d.f): 417.58 (44)				

*** Significance at 1%.
** Significance at 5%.
* Significance at 10%.

Table 3. Results of the multinomial logit estimation

Two important points emerge from these findings. First, external knowledge sourcing seems to be m ore important for radical innovation than for incremental innovation. This is not surprising, since the former usually involves greater technical and market uncertainty, making it necessary for the firm to cooperate or outsource R&D services in order to spread the risks of the innovation activity (**Tether, 2002**).Our results provide further support for the idea that working closely with users or customers improves the firm's innovative performance (**Von Hippel, 1976, Rothwell, 1977; Laursen and Salter, 2006**). However, despite of the importance of some external knowledge sources, our findings also indicate that innovation is a process that is built largely on firms' internal capabilities. Thus, although certain types of external knowledge sourcing strategies (e.g. cooperation with clients or acquisition of machinery) are associated with certain types of innovation, this does not imply that the introduction onto the market of new products necessarily depends on the firm's ability to build strong links with external agents. In-house R&D activity represents a strategic asset in the development of new products and, also, development and implementation of these activities is significantly more important than employing strategies involving external partners[6].

In terms of the control variables, the proportion of employees with a higher education degree, the firm's size and export orientation and the technological intensity of the industrial sector are all positively and significantly associated with incremental and radical innovation. These results are consistent with previous research showing that firms with more resources, with more highly-skilled personnel and operating in sectors that are relatively high R&D intensive are more likely to develop new products **(Amara and Landry 2005; Miotti and Sachwald, 2003;Vega-Jurado et al., 2008).** However, whether or not the firm belongs to a group or whether the firm is a start-up were found not to be related significantly to product innovation.

Finally, we conducted supplementary analyses to test whether our results were being driven by alternative explanations. One of the main assumptions in this paper is that the strategies adopted to promote innovation produce an impact in a subsequent period. Although this is a plausible assumption, we cannot rule out the possibility that the impact on product innovation of some strategies (including cooperation) may occur more quickly. To address this point, we carried out additional checks using a new set of

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[6] In-house R&D has the highest coefficient for the two types of innovations analysed.

explanatory variables indicating 'persistence' of the innovation strategies[7]. For university cooperation, the new variable takes the value 1 if the firm indicates engagement in active cooperation with universities during the 2002-2004 and 2005-2007 periods. We adopted a similar procedure to define the variables related to R&D outsourcing, in-house R&D, acquisition of machinery and acquisition of other external knowledge. The results of these analyses are generally consistent with the reported findings, especially those related to the effect of knowledge acquired from universities. We also conducted a group analysis for the three sectoral categories: high, medium and low-technology. Overall, the results related to the effect of university industry interaction (via cooperation or outsourcing) hold for each of the three groups separately (although some differences appear in relation to the effect of the other innovation strategies)[8].

We also examine if the firm's knowledge base moderates the relationship between interaction with universities and product innovation. **Cohen and Levinthal (1989, 1990)** point out that a firm's knowledge base enhances the effectiveness of externally sourced technology by providing the means to understand and utilise the information acquired. On this basis, it has been argued that the greater the internal capabilities of the firm, the greater will be the effects of the different external knowledge acquisition strategies on innovation performance. In order to test this moderator effect, we carried out some additional checks, including interaction terms between the two types of knowledge sourcing strategies from universities (cooperation and R&D outsourcing) and two proxy variables for firm's knowledge base (in-house R&D and percentage of employees with a higher education degree). Our results do not support the hypothesis

[7] This approach is similar to that of Belderbos et al (2004b).
[8] E.g., acquisition of machinery and equipment and outsourcing of R&D services to other firms have a significant effect on low-technology firms, while for high-technology firms, in-house R&D is the only strategy that is positive and significant.

(the interaction terms are insignificant in all cases), suggesting that the firm's internal capacity does not seem to increase the effects on innovation of knowledge acquired from universities. However, more research on this topic needs to be undertaken.

5 Discussion and Conclusions

The importance of external knowledge sourcing from universities as a determinant of industrial innovation has been emphasised in the recent literature, within several theoretical approaches. Likewise, the promotion of university–industry relationships ranks high on the current agendas of many OECD country governments. This paper provides an empirical analysis of whether these types of interactions really impact on firms' innovation performance, in the context of a technology-follower country and based on a large-scale, cross industry sample. We focused on the link between the degree of novelty of innovation and two channels of knowledge from universities: 1) cooperation in innovation activities; and 2) contracting out of R&D services.

The results show that the higher the technological intensity of the sector in which the firm operates, the higher the level of cooperation with scientific agents. Furthermore, the firms in these sectors tend to invest more in external R&D performed by universities and research institute than firms belonging to low-technology sectors. However, the results show also that, even in high technology sectors, the interaction between firms and universities has no significant effect on product innovation, through either cooperation or the acquisition of external R&D. These findings support previous research in this area suggesting that universities rarely act as direct sources of knowledge for innovative activities in firms, especially in technology-follower countries.

In Spain, as in other OECD countries, since the beginning of 2000, governments have launched several programmes to encourage closer relations between firms and universities. These initiatives could explain why Spanish firms tend to cooperate more with universities relative to other external agents (e.g. clients, consultants). However, our results show that this type of cooperation does not seem to improve the development of activities that are important for firms' innovation processes. It is possible that in the Spanish context cooperation between firms and scientific agents is motivated more by access to funds through participation in government sponsored programmes, than by improving innovative capacity based on the integration of complementary knowledge from external agents. However, this remains a hypothesis and will need further work to prove or disprove it.

Our results show that links with clients are an important strategy for Spanish firms to develop radical innovations. Also, acquisition of machinery and equipment and outsourcing of R&D services to other firms are significant for radical innovation in firms. These results suggest that innovations that embody more radical changes in products require knowledge from external agents, in contrast to incremental innovations which can be achieved based on internal knowledge from in-house R&D. In-house R&D is also the main determinant of product innovation.

There are several important implications for policy from these results. First, since innovation output largely depends on in-house R&D activities, strengthening the internal capabilities of firms might be more beneficial than the fostering cooperation per se. Thus, indirect interventions, such as reducing the costs involved in highly qualified personnel or promoting the mobility of researchers between university and industry, might be more effective initiatives. Second, in order to increase the novelty of innovation, it is important to promote links between firms and external agents, but this should go beyond simple support for university-industry relations and emphasise other external sources of knowledge.

Finally, we should highlight some limitations of this study. First, we use only one measure of innovation: degree of novelty of product innovation. It would be interesting to investigate whether interaction with universities has a significant effect on other innovation outputs (e.g. process innovation, patent applications). Second, our analysis is restricted to manufacturing firms. Given the significance of services in advanced economies, it would be useful to know whether the behaviour of service firms related to the acquisition of external knowledge is similar to, or different from the behaviour of manufacturers. Third, our study is restricted to the Spanish context; further comparable studies would be welcome.

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